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ICRP PUBLICATION 82 ON PROTECTION AGAINST PROLONGED EXPOSURE - APPLICATION IN ACCIDENT SITUATIONS

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1 Introduction

In the past 15 years, two events have occurred that cover a conceivable range of emergencies involving extensive post-emergency phase response, namely the Chernobyl and Goiânia accidents. Large amounts of ^{137}Cs were released to the environment during these accidents, leading to a prolonged or quasi-prolonged exposure of the affected populations. The experience gained from these accidents and others have revealed that there is a need for an updated and fully integrated system of guidance on implementation of countermeasures. A revised system must have a sound technical basis but must also be understandable, explainable and acceptable to the public and the decision-makers. Once all protective actions have been undertaken, the situation should be considered 'normal' again with no further restriction being imposed. Therefore a common language explanation should be developed for the public and public officials that clearly state the risks of radiation exposure and what actions are appropriate and inappropriate, and what is "safe". The concepts of "safe" and "return to normality" should be developed together with intervention criteria, disengaged from the linear non-threshold risk hypothesis. Within this context, the application of the recommendations in ICRP Publication 82 for application in post-accident situations is briefly summarized with reference to observations and lessons learned from the Chernobyl and Goiânia accidents.

2 Radiation protection in prolonged exposure situations

ICRP has recently published guidance on protection of the public against prolonged radiation exposure[1]. Prolonged exposures are adventitiously and persistently incurred by the public over long periods of time. They are incidental to situations in which members of the public may find themselves. The annual doses associated with prolonged exposures are more or less constant or decreases slowly over the years. Generic reference levels for intervention in prolonged exposure situations, expressed in terms of existing annual dose, are recommended by the ICRP; these levels should be viewed as a *consequential* derivation from the basic ICRP principles of radiological protection for intervention and as *complementary*, rather than alternative, to those principles. Their use should not preclude the application of these basic principles to any dose component of the existing annual dose that is controllable, particularly if it is a dominant component.

2.1 Sources of prolonged exposure

Situations of prolonged exposure of the public include the prolonged background exposure and the exposure from human-made radiation sources. The prolonged background exposure varies with the geographical and geological characteristics but also with features associated with human development. The human-made radiation sources causing prolonged exposure would arise from a number of human activities associated with the development of society.

[1] INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, *Protection of the Public in Situations of Prolonged Radiation Exposure*. Publication No. 82, Pergamon Press, Oxford, New York (2000).

The natural sources, which are responsible for the prolonged exposure, are the external cosmic radiation, the radionuclides produced by cosmic rays in the atmosphere (*e.g.* ^{14}C and ^{3}H), and the radionuclides of uranium and thorium in the earth's crust. The exposure pathways include external exposure and inhalation and ingestion of radionuclides in air, food and water.

Prolonged exposures of the public from human activities usually result from releases of long-lived radionuclides into the environment. Residues containing long-lived radionuclides from past human activities that were not adequately controlled are one example. Others are current practices, some past industrial applications, especially mineral extraction, military operations and nuclear or radiological accidents. Figure 1 presents a schematic illustration of various sources of prolonged exposure.

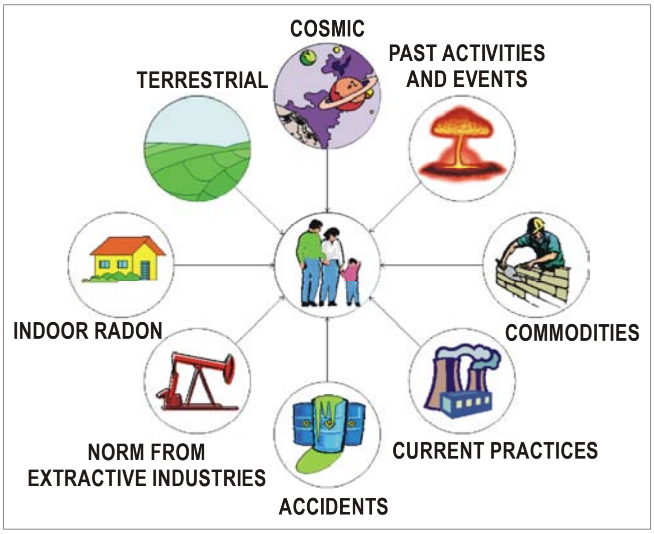

Figure 1. Schematic presentation of various sources of prolonged exposure. They include a number of natural and artificial sources. The sum of exposures to the sources present in a human habitat results in an ***existing annual exposure*** *to the individuals living there.*

The operation of practices may leave long-lived radioactive residues in the environment, resulting in situations of prolonged exposure. Practices may also generate prolonged exposure situations due to the disposal of radioactive wastes. Radioactive residues from practices can either result from normal discharges to the environment or remain on and around the site of a practice after the cessation of the practice and decommissioning of its installations.

Intervention situations involving prolonged exposure are of various types. In all cases, decisions have to be taken on whether and how to intervene in order to reduce these exposures and, eventually, on whether and when to discontinue protective actions. The classical intervention situation is where people are already incurring exposures attributable to an identifiable event relatively close in time, *e.g.*, a nuclear or radiological accident. Another type is, for example, exposures to natural sources and to radioactive residues that cannot be linked to any particular originating cause or where the link to the cause has weakened over time.

2.2 Reference levels for intervention in prolonged exposure situations

In the ICRP 82 the relevant dosimetric quantity for controlling prolonged exposures is the *annual effective dose*. This is the sum of the time integral, over a year, of the effective dose rate due to external irradiation caused by the prolonged exposure situation and the committed effective dose due to internal contamination caused by all intakes, during that year, of the long-lived radionuclides (and their short-lived progeny) involved in the situation. A subsidiary quantity used within the context of prolonged exposure is the *existing annual dose* caused by all persisting sources of prolonged exposure in a given situation. Other subsidiary quantities are the *addi-*

tional annual dose caused by practices and the *averted annual dose* precluded by an intervention.

The existing annual dose can conceptually be used to establish *generic reference levels* for intervention. However, such quantity should be used with caution. It is made up of all the existing and persisting annual doses incurred by individuals and, therefore, it is constituted by many different components of prolonged exposure. These include external exposure to long-lived radionuclides (and their progeny) in soils, strata, and building materials (including exposure to radon and other radionuclides in the ambient), internal exposure due to the incorporation of those radionuclides into the body as a result of inhalation of resuspended materials, and ingestion of contaminated foodstuffs.

There is not a single measure that can be used to determine the value of the existing annual dose, as any of its components may require different assessment methodologies. Thus, there may be practical problems in implementing regulatory standards expressed in terms of the existing annual dose. Because of these difficulties, the ICRP 82 has given preference to *specific reference levels* based on avertable annual doses of given components, rather than to generic reference levels based on existing annual doses. The ICRP 82 recommends that:

(a) *An existing annual dose approaching about 10 mSv may be used as a generic reference level below which intervention is not likely to be justifiable for some prolonged exposure situations.*

(b) *Below the level of existing annual dose for which intervention is not likely to be justifiable, protective actions to reduce a dominant component of the existing annual dose are still optional and might be justifiable. In such cases, action levels specific to particular components can be established on the basis of appropriate fractions of the recommended generic reference level.*

(c) *Moreover, above the level of existing annual dose for which intervention is not likely to be justifiable, intervention may possibly be necessary and its justification should be considered on a case-by-case basis as appropriate.*

(d) *Situations in which the annual (equivalent) dose thresholds for deterministic effects in relevant organs could be exceeded should require intervention.*

(e) *An existing annual dose rising towards 100 mSv will almost always justify intervention and may be used as a generic reference level for establishing protective actions under nearly any conceivable circumstance.*

In general, ICRP concludes that the use of generic reference levels should *not* encourage a ‘trade-off’ of protective actions among the various components of the existing annual dose. In this regard the ICRP considers that a low level of existing annual dose does not necessarily imply that protective actions should not be applied to any of its components; and, conversely, a high level of existing annual dose does not necessarily require intervention. Should intervention be considered justifiable, the form, scale and duration of the protective actions should be optimised.

2.3 ICRP 82 generic reference levels in perspective

The identification of existing annual doses low enough to make intervention usually not to be expected, and not likely to be justifiable, is not simple and certainly not straightforward. For perspective purposes, it is helpful to use the ‘natural’ existing annual doses experienced in many parts of the world. The global average ‘natural’ dose is 2.4 mSv/a, but many large populations have lived for years in areas of the world experiencing typically elevated doses of up to around 10 mSv/a, with some populations even incurring doses above 100 mSv/a. In many of the places experiencing high levels of background radiation, the dominant component of exposure is that to the gas radon in dwellings; in other situations, the exposure is mainly caused by other gamma-emitting radionuclides, such as radium in soil and water.

With some exception, intervention has rarely, if ever, been undertaken to reduce the typically elevated 'natural' background doses of about 10 mSv/a. Moreover, only occasionally have protective actions been implemented to reduce higher 'natural' background doses, even when these doses were controllable. This might suggest that competent authorities have considered these levels as being unlikely to trigger any intervention in those situations.

Moreover, the ICRP considers that a high level of existing annual dose - *e.g.*, due to high natural background levels - should not justify *per se* a particular component of annual dose - *e.g.*, a high level of annual dose attributable to long-lived radioactive residues. This should always be restricted following the principles of the System of Radiological Protection for intervention. However, as the expected radiation health effects depend on the dose received and not on the source origin, the ICRP also considers that the typically elevated levels of existing annual doses from 'natural' sources, which have not triggered any protective action, may provide a useful insight into decisions related to intervention.

Further insight on sufficiently low levels of existing annual doses can be obtained from earlier recommendations given in ICRP Publication 63[2] and in ICRP Publication 65[3]. In these publications a number of intervention situations including some involving prolonged exposure were addressed. Specific reference levels below which any intervention or action is unlikely to be taken in various situations were here recommended, suggesting levels ranging from a few to a few tens of mSv for a dominant single component of the existing annual dose. Such intervention and action levels have been generally incorporated into international standards[4] and some national regulations. Again, this suggests that governmental authorities have considered the recommended levels (of around 10 mSv/a) as being unlikely to trigger intervention.

3 Response to nuclear or radiological emergencies - principles and experience

The International Commission on Radiological Protection (ICRP) has indicated that its basic framework for radiological protection is intended to prevent the occurrence of deterministic effects, by keeping doses below the relevant thresholds, and to ensure that all reasonable steps are taken to reduce the induction of stochastic effects. Although the ICRP policy for radiation protection has evolved over the years, its main objective has remained basically unchanged. It was formulated in the latest recommendations from ICRP (Publication 60) as: *The primary aim of radiological protection is to provide an appropriate standard of protection for man without unduly limiting the beneficial practices giving rise to radiation exposure*. The ICRP policy is *also* to supplement the available scientific knowledge by value judgements about the relative importance of different kinds of risk and about the balancing of risks and benefits.

3.1 Protection principles in a nuclear or radiological emergency

The System of Radiological Protection makes a distinction between *source-related* protection - which is concerned with the exposures of individuals resulting from a single source - and *individual-related* protection - which is concerned with the exposure of a single, individual from many sources. Provided that the individual doses are well below the threshold for deterministic effects, the contribution to an individual dose from a single source has an effect that is independent of the doses from other sources. For many purposes, each source, or group of sources, can then be treated on its own.

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[2] INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, *Principles for Intervention for Protection of the Public in a Radiological Emergency*. Publication 63, Pergamon Press, Oxford, New York, Seoul, Tokyo (1993).

[3] INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, *Protection Against Radon-222 at Home and at Work*. Publication 65, Pergamon Press, Oxford, (1993).

[4] INTERNATIONAL ATOMIC ENERGY AGENCY, *International Basic Safety Standards for Protection Against Radiation and for the Safety of Radiation Sources*. Safety Series No. 115, Vienna (1996).

Source-related assessments make it possible to judge whether a *practice* or *intervention* is likely to bring benefits sufficient to outweigh any disadvantages and whether all reasonable steps have been taken to reduce the radiation exposures that a source will cause. They thus facilitate the justification of *practices* and *interventions* and the optimisation of protection at the source level. Source-related assessments take account of the magnitude (increase or decrease) of the doses attributable to the assessed source, and of the number of individuals exposed, but not of the influence on individuals of other exposure sources.

The system of radiological protection for intervention situations is based on the following general principles of *justification* and *optimisation*:

(a) *All possible efforts should be made to prevent deterministic effects.*

(b) *The intervention should be justified, in the sense that introduction of the protective measure should achieve more good than harm.*

(c) *The levels at which the intervention is introduced and at which it is later withdrawn should be optimised, so that the protective measure will produce a maximum net benefit.*

Dose limits used in the radiation protection system for practices do *not* apply in the case of intervention, for which intervention levels in terms of *avertable dose* should be applied.

3.2 Some reflections and lessons from past emergencies

Radiation emergencies in the past have demonstrated that immediately after the emergency phase of the response, there will be immense pressure from the public, public officials and the media to act to correct the problem and return the situation to normal. Without prior arrangements, public officials, when under intense pressure to restore the situation to normal, may take highly visible actions even if these are only minimally effective or even counterproductive. During the response to Chernobyl many unjustified efforts were carried out because of this pressure, such as decontamination of areas (*e.g*. Pripyat) that were evacuated and never resettled.

The Chernobyl and Goiânia accidents demonstrated that public officials make decisions concerning implementation of countermeasures affecting the public during the post-emergency phase of a radiation emergency. These officials were not radiation specialists and they made their decisions on the basis of their understanding of both the radiological risk and of societal and political concerns. This was recognized by the ICRP[1] when it recommended that guidance for taking post-emergency countermeasures based on scientific consideration of radiation protection should serve as an input into the wider decision-making process. It is important that the decision-maker understands the guidance for dealing with the radiological risk and be able to explain it to the public and the stakeholders for it to be useful as a decision-aiding tool. Assurance that the actions being taken will guarantee the “safety” of the affected populations should therefore be elaborated by the radiation protection community, disengaged from the linear non-threshold (LNT) risk hypothesis.

Following radiation emergencies the public took inappropriate and in some cases harmful action due to fear and misunderstanding concerning radiation risks and how to reduce them (*e.g.* refusing to buy products from the area, refusing to sell airline tickets to people from the area, having abortions due to a fear of radiation induced effects, and refusing to provide medical treatment to victims). These fears were in part due to the use of the LNT hypothesis by unofficial sources, the use of cryptic technical terms and the reluctance of technical experts to provide the definitive guidance needed and wanted by the pubic. Therefore, the LNT hypothesis should be reconsidered as basis for decisions on countermeasures.

Experience shows that international guidance does not address many post-emergency countermeasures that should be implemented, in part, based on radiation protection principles and insights. These include personal monitoring and decontamination, decontamination of property, release of contaminated property for use, initial medical screening, long-term medical follow-up, contaminated non-food products, and termination of countermeasures (‘return to normality’).

The ICRP[1] and others[5] have pointed out that it is impossible to anticipate or address factors not directly related to radiation protection principles when developing radiation protection guidance. Attempting to consider other factors or anticipate what would be acceptable to the public would only undermine the technical foundation of the recommendations, making them difficult to apply consistently, adjust or explain. It is the role of the radiation protection expert to give the best professional advice, even if the decision-maker, bowing to the pressure of political or public opinion, subsequently ignores it. Therefore, international guidance on interventions after an accident should be based *solely* on radiation protection considerations.

4 Applying ICRP 82 in an integrated framework of emergency response

A fully integrated system for implementation of countermeasures must have a sound technical basis but must also be understandable, explainable and acceptable to the public and to decision-makers. The essence of the guidance is that it must do more good than harm (be justified) and assure the public that they are safe. The ICRP 82 recommendations were developed for prolonged exposure situations, and they can be used as basis for an integrated system of radiological protection in emergency situations with special emphasis on the radiation protection of populations affected by nuclear accidents (*e.g.* Kyshtyhm, Chernobyl) or radiological accidents (*e.g.* Goiânia) in the post-emergency phase.

The radiation protection strategy for a population affected by a nuclear or radiological accident should first of all do everything possible to avoid serious deterministic effects and should thereafter implement protective actions with the aim of averting doses to the population to a *safe level*. Once all required protective actions have been undertaken, the situation should be considered 'normal' again with no further restriction being imposed.

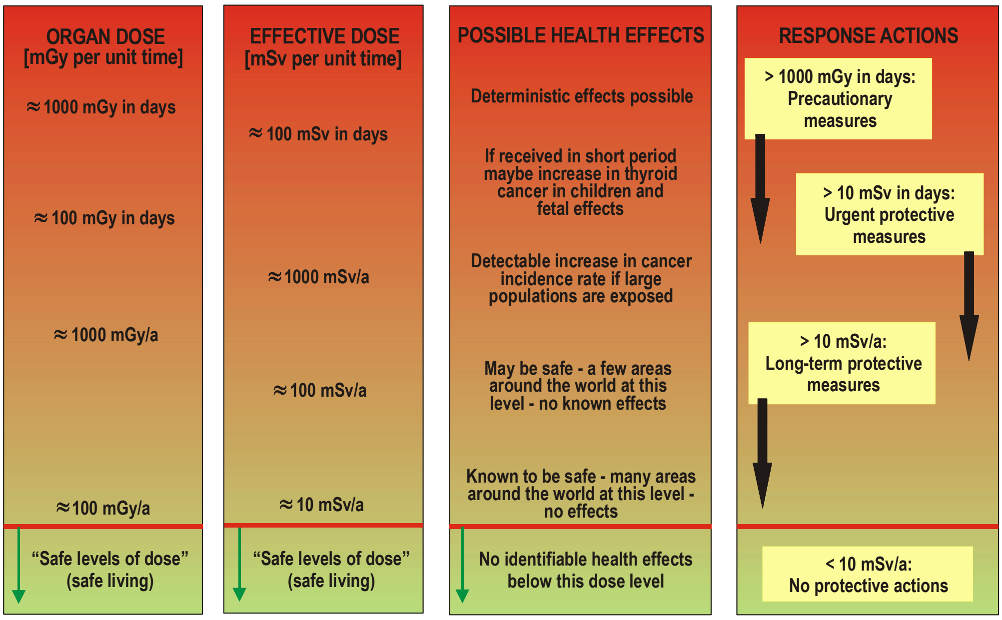

Figure 2. Protection strategy following a nuclear or radiological accident. At very high levels of individual dose preventive and urgent protective actions should be implemented to prevent deterministic effects and high probabilities of stochastic effects. At lower individual dose levels countermeasures should be implemented to avert doses to the affected population to reduce the stochastic effects and to restrict the residual individual dose level to a safe level. This level can be regarded as level for safe living conditions after a protective measure has been lifted (or considered but not implemented).

[5] INTERNATIONAL ATOMIC ENERGY AGENCY, *Restoration of Environments with Radioactive Residues*. Proceedings of an International Symposium, Arlington, Virginia, USA, 29 November - 3 December 1999. IAEA, Vienna (2000).

Figure 2 illustrates the protection strategy after a nuclear or radiological accident: all effort should be done to avoid deterministic effects, and the reduction in expected stochastic effects should be based on optimized intervention and action levels to achieve a safe level, which can be defined as:

(1) From a radiation protection point of view "safe" means that population or critical subgroups will not receive a total annual dose leading to *identifiable* adverse health effects; "safe" does, however, *not* mean zero risk.

(2) Normal living conditions means that members of the public can live without any significant disrupting restrictions. Safe conditions are when people are living in normal living conditions or are following restrictions associated with radiation exposure.

(3) A total annual effective dose of about 10 mSv can be used as a reference level for safe living conditions. However, if a process of justification and optimization results in different (higher or lower) dose levels, these should be applied in that given situation.

The system of radiological protection for interventions can be rephrased based on the following principles:

(a) *Actions to avoid serious deterministic effects should almost always be undertaken*

(b) *Protective and remedial actions should be based on justified and optimised specific intervention levels and action levels*

(c) *The population affected by a nuclear or radiological accident should be safe after protective and remedial actions have been implemented (individual effective doses < 10 mSv/a)*

The rephrased system of radiological protection for interventions in emergency situations is illustrated in Figure 3.

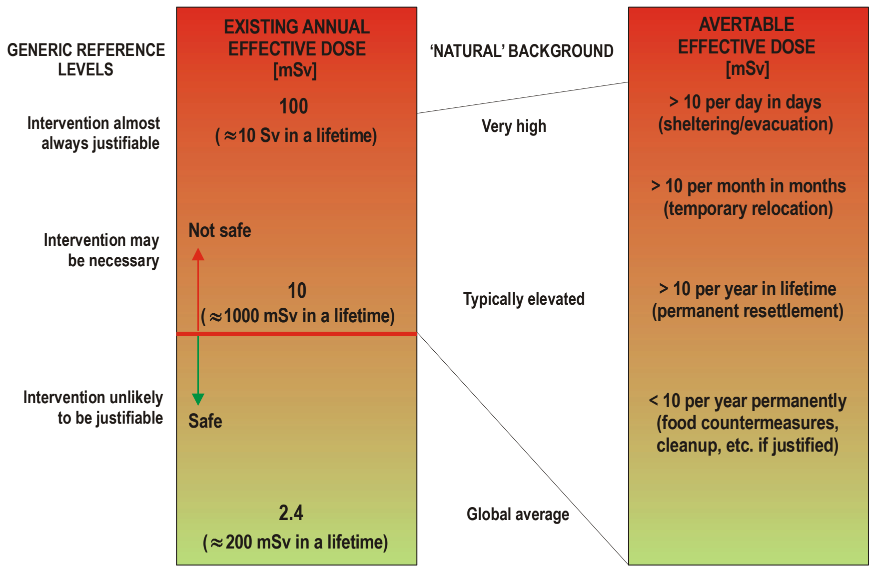

Figure 3. Schematic representation of the system of protection in emergency situations with an upper bound of the generic intervention levels of existing dose vis a vis the specific intervention levels of avertable dose. The specific intervention and action levels have been set to give an optimum reduction in individual doses. The exposure level to be compared with the intervention/action levels is the average individual dose in the critical group.

An annual effective dose of about 10 mSv (3 - 5 % additional average lifetime risk of fatal cancer if lifetime is taken to be 60 - 100 years) represents an upper bound on residual annual dose dividing exposure situations into two "classes". Situations with annual effective doses to the critical group above this level would normally not be considered as normal. In cases where the residual dose is characterized as “normal” it would henceforth be considered “background”. In addition, a high level of existing annual dose should not preclude the introduction of a new practice, as a practice is controlled through the additional annual dose attributable to the practice rather than through the existing annual dose.

5 Conclusions

The Chernobyl and Goiânia accidents clearly demonstrated the need for recommendations on ‘normal’ or ‘safe’ living conditions in post-accident management. The USSR lacked criteria for implementation of countermeasures and return to normality (ending countermeasures) at the time of the Chernobyl emergency. In the years after the Chernobyl accident, the former Soviet Union - due to public pressure - adopted criteria for resettlement and other countermeasures that were not founded on established radiation protection principles. In the opinion of many radiation protection professionals, the criteria were not justified and probably have done more harm that good. During the response at Goiânia, it was very difficult to set operational levels for post-emergency intervention that were consistent with internationally accepted scientific principles because of time constraints and political pressure. This resulted in the use of the dose limit for practices as a basis for intervention and consequently in protective actions, generation of contaminated waste and decontamination and disposal costs that did not appear to be justified on radiation protection grounds.

The recommendations in ICRP Publication 82 were developed to fill a long experienced gap with regards to radiation protection against exposure from long-lived radionuclides in the environment, including those originating from radiological or nuclear accident. The recommendations are based on objective assessments of the health risks associated with prolonged exposure levels and on radiological protection attributes of various exposure situations. Typically elevated prolonged exposures due to natural radiation sources are usually ignored by society, while relatively minor prolonged exposures to artificial long-lived radioactive residues are a cause of concern and sometimes prompt actions that are unnecessary in a radiological protection sense. This reality of social and political attributes, unrelated to radiological protection, usually influences the final decision on the level of protection against prolonged exposure. Therefore, while ICRP 82 should be seen as a provider of decision-aiding recommendations mainly based on scientific considerations on radiological protection, the outcome of its advice will be expected to serve as input to a usually wider decision-making process.

Based on the radiation protection recommendations in ICRP 82 a dose level of *10 mSv per annum* can be used as a reference level for ‘safe living conditions’ or ‘return to normality’ after protective measures have been lifted (or considered but not implemented). The definition of ‘safe’ in the context of residual radiation exposure of population groups is that *no* radiation induced adverse health effects can be *observed*, and, equally important, that the residual risk for developing such health effects is low for the affected individuals.